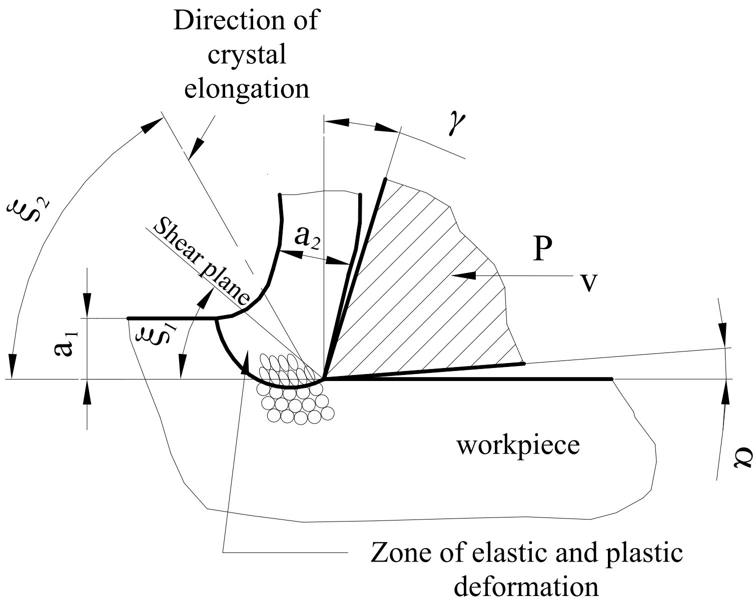
4 Chip formation

4.1 Basic concepts of chip formation

The chip which is a part of workpiece material is being produced by the main cutting edge, the nose and a small part of the secondary cutting edge of the tool. The transformation of the workpiece layer into the chip is often studied by means of an experimental technique using a quick stop device which stop suddenly the cutting action and the chip being generated is frozen on the workpiece.

The formation of chip is very complicated process:

When machining → Cutting force P → plastic and elastic deformation in cutting zone → $\sigma \uparrow$ in plane of maximum elongation ξ_2 and with continuous tool penetration → shear stress ↑ and plastic deformation ↑ → element of chip is sheared-off along shear plane ξ_1.

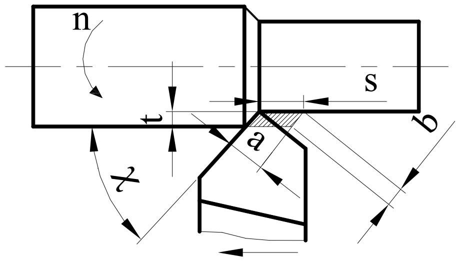


4.2 Criteria of the degree of chip deformation:

4.2.1 Shear angle ξ_1: (Deformation ↑ → a_2 ↑ → ξ_1 ↓)

The angle ξ_1 can be determined experimentally when the process of cutting is interrupted suddenly using quick-stop device and a sheared-off part of material can be obtained. Using a photographic picture with magnification ξ_1 is determined.

4.2.2 Coefficient of chip upsetting (k):



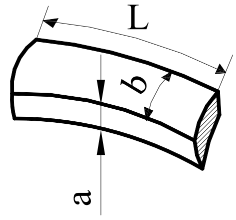
If: a …… chip thickness before chip formation.

b …… chip width

Then theoretical cross-section area of chip is:

$$F_t = a \times b = s \times t$$

but actual area will be different due to deformation.



Chip segment

Considering equal volume ($V_1 = V_2$):

Where

V_1 and V_2 are volume of chip before and after cutting.

$$a_1 \times L_1 \times b_1 = a_2 \times L_2 \times b_2$$

If: $b_1 = b_2$

Then $a_1 \times L_1 = a_2 \times L_2$

$$\frac{a_2}{a_1} = \frac{L_1}{L_2} = k > 1$$

Where k is the coefficient of chip upsetting. When deformation ↑ → a_2 ↑ → K ↑

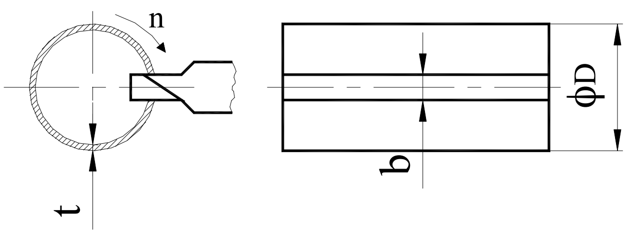
The values of a_1 and L_1 can be obtained before cutting while a_2 and L_2 are measured.

Example: A cylindrical workpiece with a longitudinal slot is used as shown in the figure where L_1 can be calculated as follows:

$L_1 = \pi(D - t) - b$

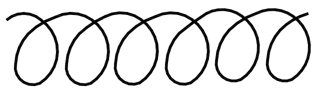
and L_2 is measured by a string.

Then $K = \dfrac{L_1}{L_2}$

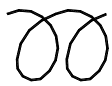


4.3 Types of chip

1. Continuous chip: It appears when machining ductile and soft materials such as Aluminum and low carbon steel and at v ↑, s ↓, γ ↑.



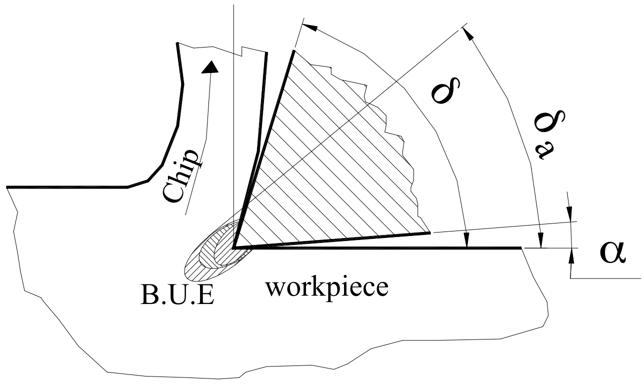
2. Sectional chip: It appears when machining hard and ductile materials such as high carbon steel and at v↓, s ↑, γ ↓.



3. Broken chip: It appears when machining hard and brittle materials such as cast iron and hard bronze and at v↓, t ↑, γ ↓.
4. For the best surface quality, it is recommended to have sectional chip.

4.4 Built-up-edge (B.U.E) formation

B.U.E consists of highly strained material adhering to the tool tip. The normal pressures between the chip and the tool are very high (1000 – 2000 Mpa) and the temperatures at the contact are high (600 - 1000°C) depending mainly on the cutting speed. Under these conditions, a layer of the chip material adheres to the tool.

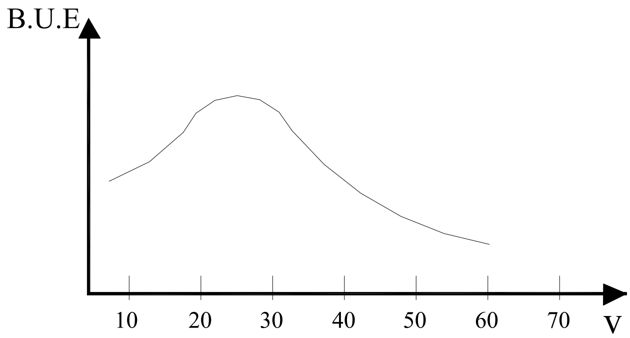


Characteristics of B.U.E

- Formed from the workpiece
- High deformation
- Non uniform microstructure
- Unstable and not uniform in size.
- High hardness.

Condition favoring BUE formation

1. High plastic properties of workpiece material
2. Moderate cutting speed v (20 – 30), mild steel.
3. ↑↑ friction on tool face
4. Similarity between workpiece material and tool material (for adhesion)
5. Pure metallic contact (no oxides)



Advantages of B.U.E

- $\delta_a < \delta$ → easy tool penetration.
- Protect main cutting edge → high wear resistance.
- Protect main cutting edge against heat.

Disadvantages of B.U.E

- Bad surface roughness of the machined surface .
- Bad accuracy of the machined surface due to machine tool vibration and due to variation in the depth of cut (t).
- Due to instability of the B.U.E formation, parts of it are breaking away with particles of the cutting edge and thus increase the rate of the tool wear.

How to avoid BUE formation:

1- avoid to use moderate speed (↑↑ v or ↓↓ v)

2- Using cooling liquid (to reduce the friction)

3- ↓ Plastic properties of workpiece material (adding S and Ph)

4- ↓ Ra of tool face to reduce the friction

5- ↑ dissimilarity between tool and workpiece materials (↓ weldability and adhesion)

6- ↓ weldability of workpiece material.